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(54) **AUTHENTICATION SYSTEM AND AUTHENTICATION METHOD**

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H04W 4/00 (2009.01)

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CPC **H04W 12/06** (2013.01); **G06F 21/34** (2013.01); **H04W 4/008** (2013.01)

(58) **Field of Classification Search**
CPC H04W 12/06; G06F 21/31
See application file for complete search history.

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(57) **ABSTRACT**

An authentication system, an authentication device, and an authentication method are provided. The authentication system includes a mobile device and an authentication device. The mobile device includes a storage unit, and a code-for-authentication generator. The authentication device includes an output device configured to output the prescribed code to be used for generating the code for authentication, an input device configured to obtain the code for authentication output from the mobile device, an authenticator generation unit, and an authentication processing unit configured to determine whether the user at the mobile device is authenticated. The authentication device includes an output device, an input device, and processing circuitry. The authentication method performed by the authentication device includes outputting, reading, and determining whether the user at the mobile device is authenticated.

16 Claims, 11 Drawing Sheets

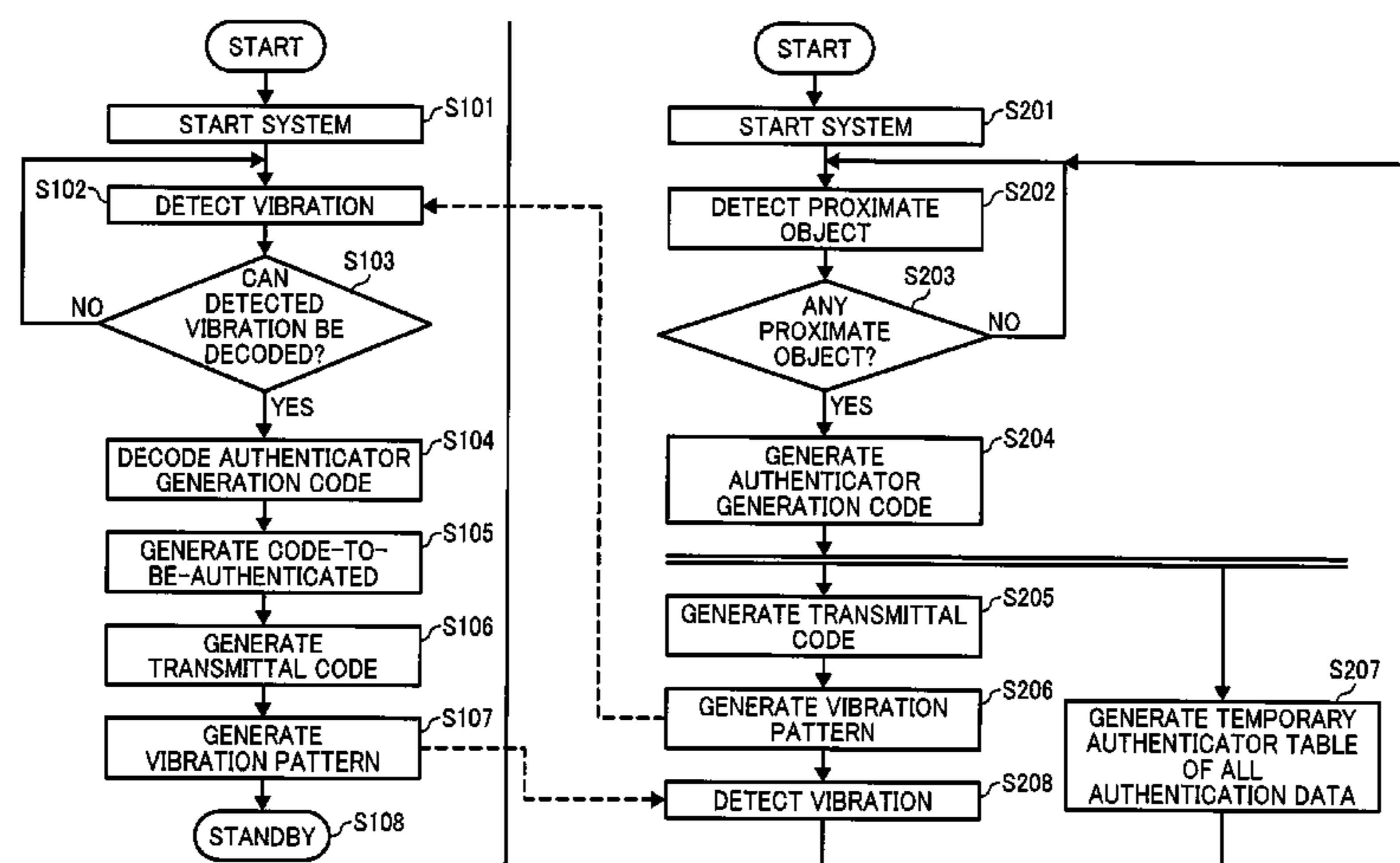


FIG. 1

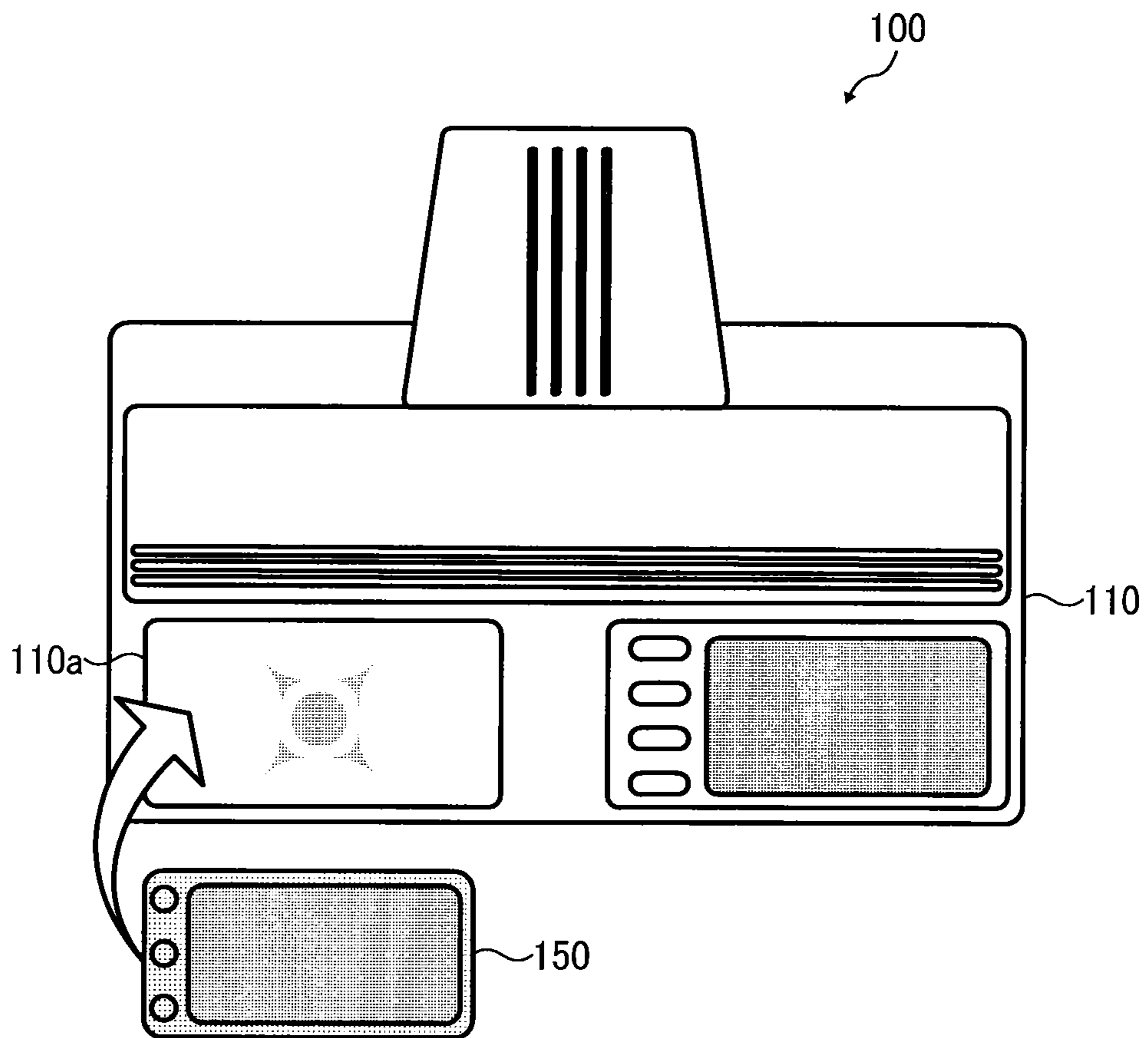


FIG. 2

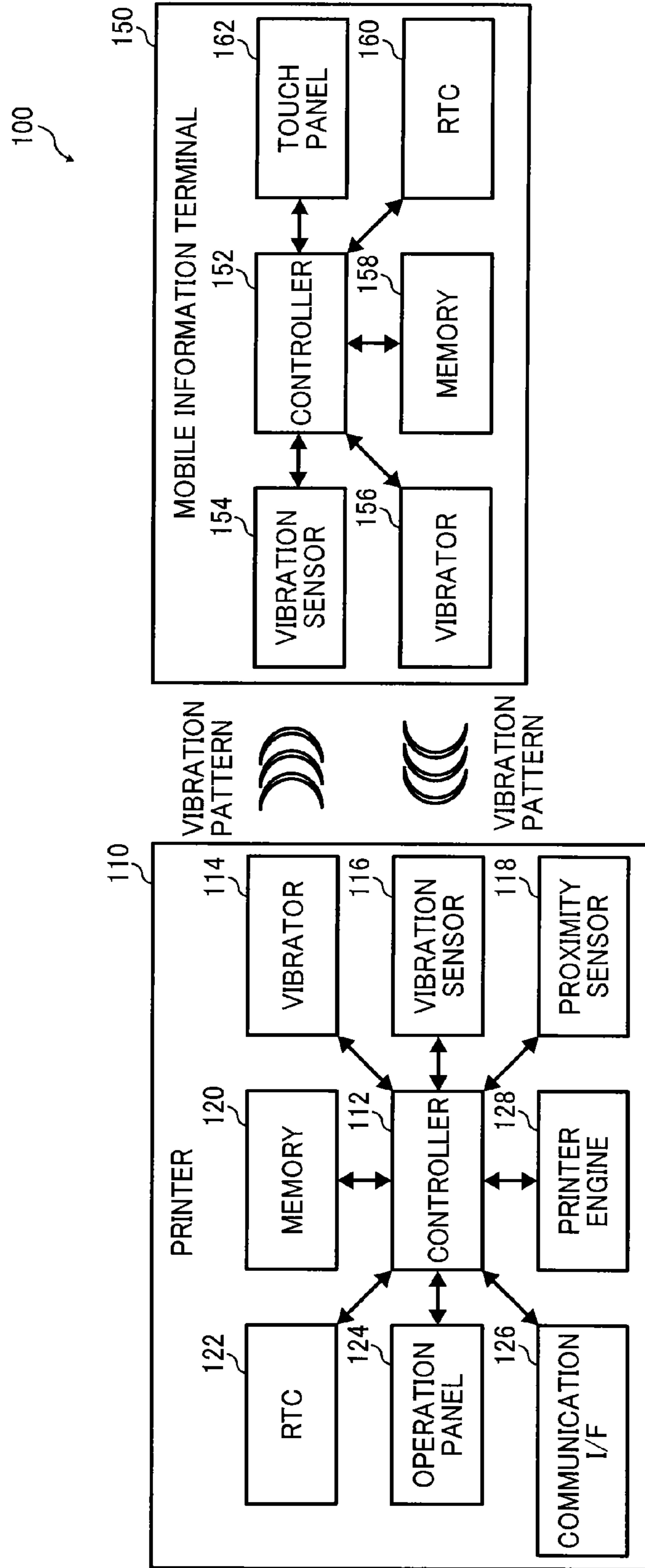


FIG. 3

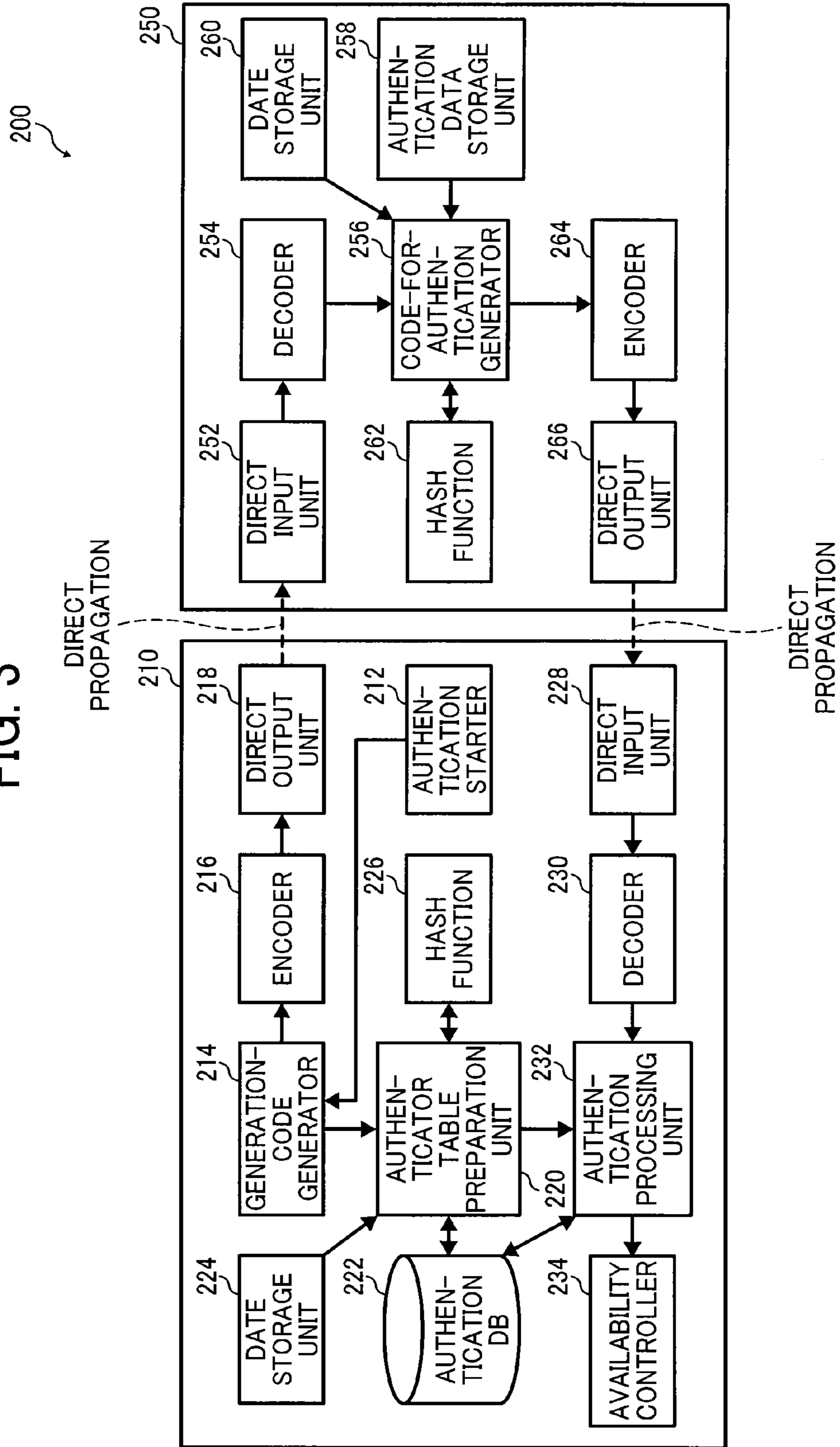
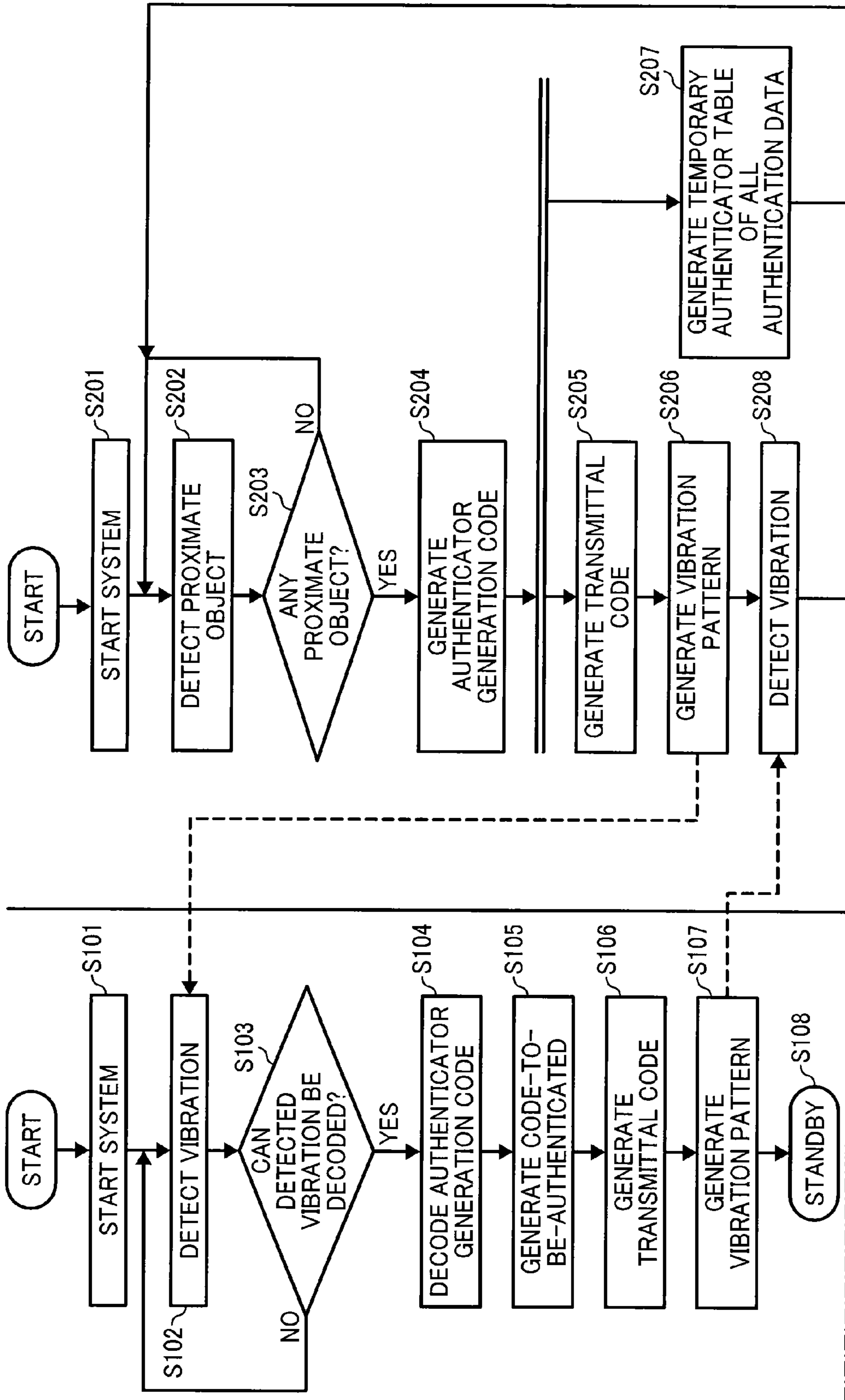


FIG. 4A



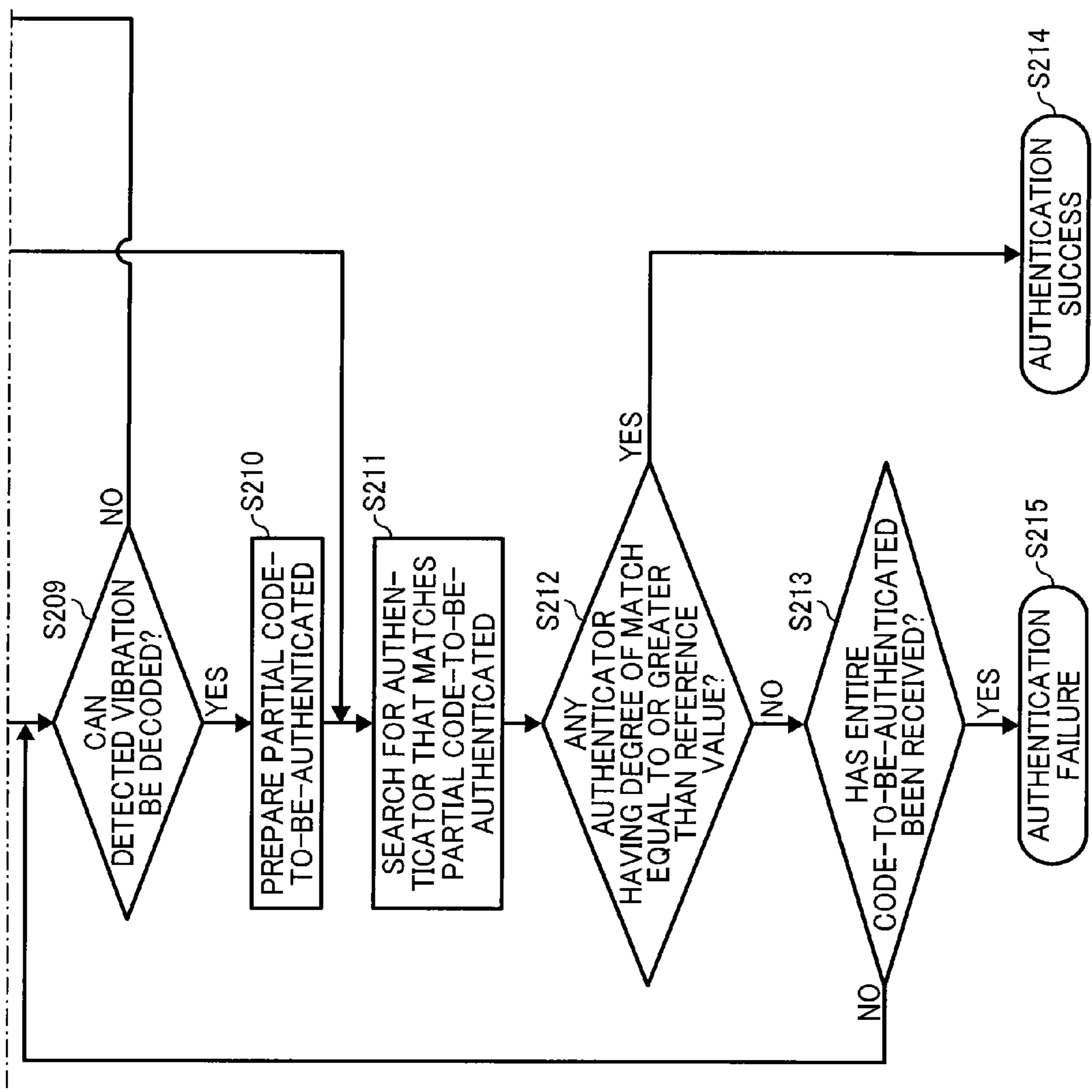


FIG. 4B

FIG. 5A

AUTHENTICATOR GENERATION CODE

0 × 12	0 × 34	0 × 56	0 × 78
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FIG. 5B

DATE DATA

'2'	'0'	'1'	'3'	'1'	'2'	'3'	'1'
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FIG. 5C

AUTHENTICATION DATA

(VARIABLE-LENGTH STRING)

FIG. 5D

AUTHENTICATION DB

USER ID	AUTHENTICATION DATA
USER 1	abc...b
USER 2	bcd...g
USER 3	cde...u
⋮	⋮

FIG. 5E

TEMPORARY AUTHENTICATOR

(FIXED-LENGTH BIT PATTERN)

FIG. 5F

TABLE

USER ID	AUTHENTICATION DATA	TEMPORARY AUTHENTICATOR
USER 1	abc...b	0100...1100
USER 2	bcd...g	1101...0011
USER 3	cde...u	0101...1001
⋮	⋮	⋮

FIG. 7A

AUTHENTICATION DB

AUTHENTICATION DATA
1001abc...b
1002bcd...g
⋮
7003cde...u
7004cde...u
⋮

FIG. 7B

TABLE

AUTHENTICATION DATA	TEMPORARY AUTHENTICATOR
0001abc...b	0100...1100
0002bcd...g	1101...0011
0003cde...u	0101...1001
⋮	⋮
6999ghj...u	0101...1101

FIG. 8

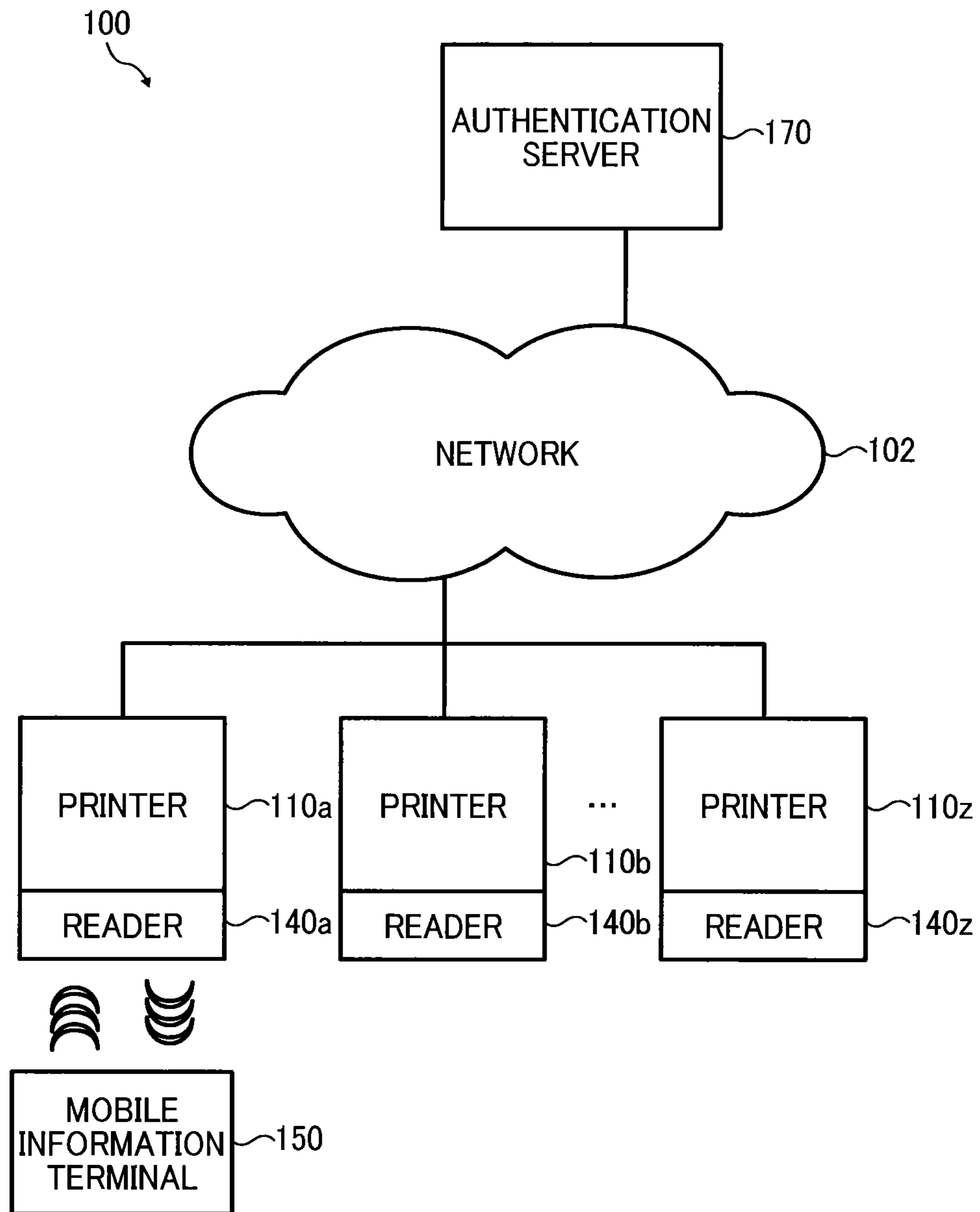


FIG. 9

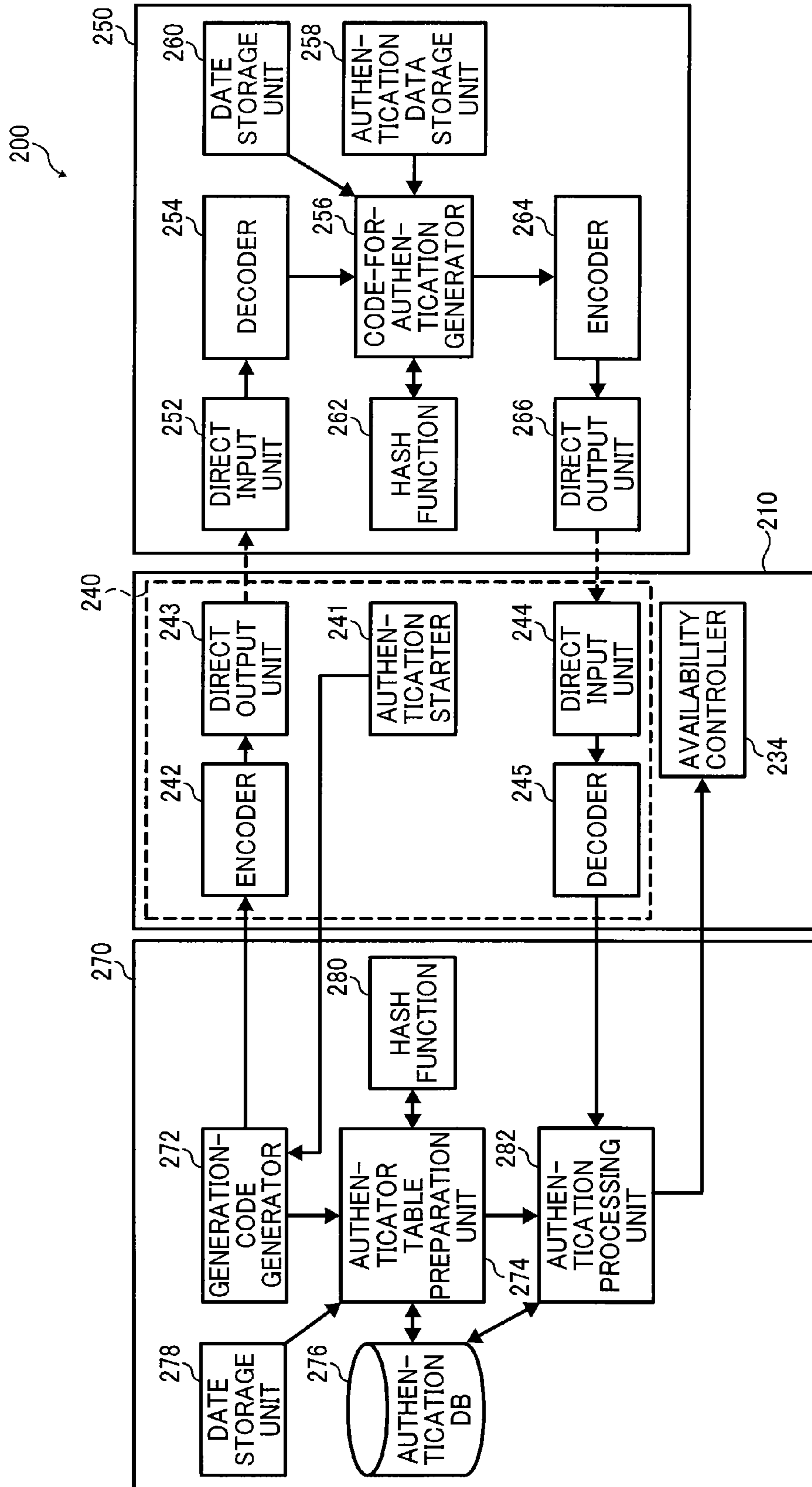


FIG. 10

TABLE

TEMPORARY AUTHENTICATOR	FIXED-LENGTH BIT PATTERN		
USER ID	AUTHENTICATION DATA	TEMPORARY AUTHENTICATOR	INVALIDITY FLAG
USER1	abc...b	0100...1100	False
USER2	bcd...g	1101...0011	False
USER3	cde...u	0101...1001	True
⋮	⋮	⋮	⋮

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AUTHENTICATION SYSTEM AND AUTHENTICATION METHOD

CROSS-REFERENCE TO RELATED APPLICATION

This patent application is based on and claims priority pursuant to 35 U.S.C. §119(a) to Japanese Patent Application No. 2014-052910, filed on Mar. 17, 2014, in the Japan Patent Office, the entire disclosure of which is hereby incorporated by reference herein.

BACKGROUND

Technical Field

Example embodiments of the present invention generally relate to an authentication system and an authentication method.

Background Art

Conventionally, authentication systems are known that record the authentication data of a user on an integrated circuit (IC) card or mobile information terminal and perform the authentication of the user when such an IC card or mobile information terminal is brought into contact with the reader of an information appliance. In such systems, IC cards or mobile devices such as mobile information terminals, and readers adopt a short-range radio communication system, and exchange authentication data therebetween.

In recent years, as a technology of connecting information appliances that are physically proximate to each other through the network, the technology of encoding communication information such as an Internet protocol (IP) address for identifying a device and transmitting the encoded communication information through a special communication channel using flash patterns, light emission patterns, sound patterns, or vibration patterns is known. When such flash patterns, light emission patterns, sound patterns, or vibration patterns are used, the range that a signal can reach is limited.

SUMMARY

Embodiments of the present invention described herein provide an authentication system, an authentication device, and an authentication method. The authentication system includes a mobile device and an authentication device configured to authenticate the user at the mobile device. The mobile device includes a storage unit configured to store authentication data of a user, and a code-for-authentication generator configured to generate a code for authentication using a prescribed code and the authentication data. The authentication device includes an output device configured to output the prescribed code to be used for generating the code for authentication in response to detection of the mobile device, an input device configured to obtain the code for authentication output from the mobile device that is generated at the mobile device, an authenticator generation unit configured to obtain authentication data of one or more registered users from a memory, and generate an authenticator for each one of the one or more registered users, by using the prescribed code and authentication data of corresponding one of the one or more registered users, and an authentication processing unit configured to match the code for authentication output from the mobile device with the authenticator that is generated for each one of the one or more registered users to determine whether the user at the mobile device is authenticated. The authentication device

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includes an output device configured to output a prescribed code in response to detection of a mobile device, an input device configured to obtain a code for authentication output from the mobile device that is generated at the mobile device using the prescribed code and authentication data of a user stored in the mobile device, and processing circuitry configured to obtain authentication data of one or more registered users from a memory, generate an authenticator for each one of the one or more registered users, by using the prescribed code and authentication data of corresponding one of the one or more registered users, and match the code for authentication output from the mobile device with the authenticator that is generated for each one of the one or more registered users to determine whether the user at the mobile device is authenticated. The authentication method performed by the authentication device includes outputting a prescribed code in response to detection of a mobile device, obtaining a code for authentication output from the mobile device that is generated at the mobile device using the prescribed code and authentication data of a user stored in the mobile device, reading authentication data of one or more registered users from a memory, generating an authenticator for each one of the one or more registered users, by using the prescribed code and authentication data of corresponding one of the one or more registered users, and matching the code for authentication output from the mobile device with the authenticator that is generated for each one of the one or more registered users to determine whether the user at the mobile device is authenticated.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

A more complete appreciation of exemplary embodiments and the many attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings.

FIG. 1 is a schematic diagram of the configuration of an authentication print system according to a first example embodiment of the present invention.

FIG. 2 is a block diagram of the hardware configuration of an authentication print system according to a first example embodiment of the present invention.

FIG. 3 is a functional block diagram of an authentication print system according to a first example embodiment of the present invention.

FIGS. 4A and 4B are a flowchart of the user authentication processes performed between a printer and a mobile information terminal of an authentication print system, according to a first example embodiment of the present invention.

FIGS. 5A to 5F depict examples of the data structure of the data used by an authentication print system according to a first example embodiment of the present invention.

FIGS. 6A to 6C depict examples of the data structure of the data used by an authentication print system according to a first example embodiment of the present invention.

FIGS. 7A and 7B depict examples of the data structure of the data used by an authentication print system according to a modification of an example embodiment of the present invention.

FIG. 8 is a schematic diagram of the configuration of an authentication print system according to a second example embodiment of the present invention.

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FIG. 9 is a functional block diagram of an authentication print system according to a second example embodiment of the present invention.

FIG. 10 depicts an example of the data structure of the data used by an authentication print system according to a second example embodiment of the present invention.

The accompanying drawings are intended to depict exemplary embodiments of the present disclosure and should not be interpreted to limit the scope thereof. The accompanying drawings are not to be considered as drawn to scale unless explicitly noted.

DETAILED DESCRIPTION

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the present invention. As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “includes” and/or “including”, when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

In describing example embodiments shown in the drawings, specific terminology is employed for the sake of clarity. However, the present disclosure is not intended to be limited to the specific terminology so selected and it is to be understood that each specific element includes all technical equivalents that have the same structure, operate in a similar manner, and achieve a similar result.

In the following description, illustrative embodiments will be described with reference to acts and symbolic representations of operations (e.g., in the form of flowcharts) that may be implemented as program modules or functional processes including routines, programs, objects, components, data structures, etc., that perform particular tasks or implement particular abstract data types and may be implemented using existing hardware at existing network elements or control nodes. Such existing hardware may include one or more Central Processing Units (CPUs), digital signal processors (DSPs), application-specific-integrated-circuits (ASICs), field programmable gate arrays (FPGAs) computers or the like. These terms in general may be collectively referred to as processors.

Unless specifically stated otherwise, or as is apparent from the discussion, terms such as “processing” or “computing” or “calculating” or “determining” or “displaying” or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical, electronic quantities within the computer system’s registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

Some example embodiments of the present invention are described below, but no limitation is indicated therein and various applications and modifications may be made without departing from the scope of the invention.

[First Example Embodiment]

The first example embodiment is described below with reference to an authentication print system 100 that includes a mobile information terminal 150 and a printer 110. The mobile information terminal 150 serves as a mobile device

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that is carried by a system user, and the printer 110 serves as an authentication device that authentication processes. The operation of the printer 110 is controlled according to a result of the authentication processes.

FIG. 1 is a diagram illustrating an outline of the configuration of an authentication print system 100 according to the first example embodiment of the present invention. As illustrated in FIG. 1, the authentication print system 100 includes a printer 110 that cannot be used unless authenticated, and a mobile information terminal 150 that is carried by a user and stores authentication data on behalf of the user.

In the authentication print system 100 according to the present example embodiment of the present invention, the communication between the printer 110 and the mobile information terminal 150 is performed by mechanical vibration patterns. When the mobile information terminal 150 is placed on a placing board 110a provided for the printer 110, the printer 110 and the mobile information terminal 150 can communicate with each other as the communication units of the printer 110 and the mobile information terminal 150 contact. Data for authentication is exchanged between the printer 110 and the mobile information terminal 150 through mechanical vibration patterns. Accordingly, the authentication of a user is performed.

In the example embodiment described herein, the authentication print system 100 includes the printer 110 that controls the operation based on the result of the authentication processes, and the mobile information terminal 150 that serves as a mobile device carried by a user. However, no limitation is indicated therein, and the configuration of the authentication system may include any other information processing devices such as a scanner, copier, multifunction peripheral (MFP), fax machine, projector, and digital camera in place of a printer, or other types of device such as an access control device in other example embodiments. The mobile device may be the mobile information terminal 150 including a smartphone, tablet computer, and personal digital assistance (PDA), or any other devices that are carried by an individual such as a laptop computer and a special-purpose key.

In the example embodiment described herein, the printer 110 serves as an authentication processing device that performs authentication processes, and an authentication-required device whose operation is controlled based on the result of the authentication processes. The authentication device, the authentication processing device, and the authentication-required device may be configured as separate devices. For example, a system may be provided including an authentication server that performs authentication processes and a printer whose operation is controlled based on the result of the authentication processes. Alternatively, an authentication device may be provided as an external device in close proximity to a printer.

FIG. 2 is a block diagram of the hardware configuration of the authentication print system 100 according to the first example embodiment of the present invention. As illustrated in FIG. 2, the printer 110 includes a vibrator 114, a vibration sensor 116, and a proximity sensor 118, each of which is controlled by a program. In a similar manner, the mobile information terminal 150 includes a vibration sensor 154 and a vibrator 156, each of which is controlled by a program.

The vibrator 114 of the printer 110 generates vibration patterns at a communication unit that the mobile information terminal 150 contact, to transfer the generated vibration patterns to the vibration sensor 154 provided for the mobile information terminal 150. No limitation is indicated, but the vibrator 114 may be any vibrator that can control the

intensity of vibration, frequency, and time, or any vibration motor that can only control the on-off of the vibration at a prescribed cycle. The vibrator **114** may use the motive power of the print engine or the like of the printer **110**.

The vibration sensor **116** of the printer **110** detects the vibration patterns that are generated by the vibrator **156** provided for the mobile information terminal **150** and are transferred through the communication unit that the mobile information terminal **150** contact. No limitation is indicated, but the vibration sensor **116** may be an acceleration sensor using piezoresistance, or a displacement detector in which a spring, a movable part, and a switch are combined.

On the other hand, the vibration sensor **154** that is provided for the mobile information terminal **150** detects the vibration patterns that are generated by the vibrator **114** provided for the printer **110** and are transferred through the communication unit that the printer **110** contact. In a similar manner to the vibration sensor **116**, the vibration sensor **154** may be an acceleration sensor or a displacement detector. The vibrator **156** of the mobile information terminal **150** also generates vibration patterns at the communication unit where the mobile information terminal **150** contacts the printer **110**, to transfer the generated vibration patterns to the vibration sensor **116** provided for the printer **110**. In a similar manner to the vibration **114**, the vibrator **156** may be any vibration or vibration motor. Such a vibration motor or acceleration sensor as described above are provided for a mobile information terminal such as a known smartphone. By making use of such existing hardware, cost may be reduced.

The proximity sensor **118** of the printer **110** is arranged near the communication unit to monitor an approaching object at all times or on a regular basis. In particular, the proximity sensor **118** detects that the mobile information terminal **150** is approaching the proximity sensor **118** to start authentication procedures. In the example embodiment described below, the proximity sensor **118** detects the proximity of the mobile information terminal **150** as an event to trigger authentication procedures. No limitation is indicated, but the proximity sensor **118** may be an infrared sensor that detects infrared reflection, or a magnetic sensor that detects changes in magnetic flux.

When the communication unit of the mobile information terminal **150** (i.e., the housing of the vibrator **156** and the vibration sensor **154**) touches the communication unit of the printer **110** (i.e., the placing board for which the vibrator **114**, the vibration sensor **116**, and the proximity sensor **118** are provided), the proximity sensor **118** of the printer **110** operates to start direct communication through vibration patterns.

In the example embodiment described below, the mobile information terminal **150** is detected by the proximity sensor **118** when the mobile information terminal **150** is placed on the placing board **110a** of the printer **110**. Then, authentication procedure starts as the vibrator **114** of the printer **110** generates vibration patterns. However, a method of detecting a request for authentication procedure is not limited to the configuration as described above. In other example embodiments, a request for authentication procedure may be detected by the printer **110** as follows. Firstly, the vibrator **114** generates vibration patterns on a regular basis, and the generated vibration patterns are detected by the mobile information terminal **150**. Then, the mobile information terminal **150** generates vibration patterns in response to the detected vibration patterns, and the vibration patterns generated by the mobile information terminal **150** are detected

by the printer **110** as a request for authentication procedure. In such cases, the proximity sensor **118** may be omitted.

In the example embodiment described below, the vibrator **114** and the vibration sensor **116** are used to transfer data for authentication through mechanical vibration patterns. In such a configuration, physical contact is necessary between the communication unit of the mobile information terminal **150** and the communication unit of the printer **110** in order to transfer mechanical vibration patterns. This configuration is preferred to prevent disguise of a sender, or to prevent tampering of the communication data.

However, the direct communication method that is used by the printer **110** and the mobile information terminal **150** is not limited to methods in which mechanical vibrations are used, and any other various types of communication methods may be used as long as the direct communication between the printer **110** and the mobile information terminal **150** can be established. The term direct communication indicates a model in which an output device and an input device communicate with each other without being mediated by a relay device. It is desired that a direct communication method that is adopted by the printer **110** and the mobile information terminal **150** is a communication method where communication is performed through a special communication channel. When communication is performed through such a special communication channel, the range that a signal can reach is limited, and a signal can be transmitted only to a contacted or nearest communication unit or a signal can be received only from a contacted or nearest communication unit. In other words, it is desired to be configured such that only one device can be arranged in the range that a signal can reach.

For example, a method may be adopted that performs communication via optical patterns using a light emitting element such as light-emitting diode (LED) or cold-cathode tube and a light receiving element such as illuminance sensor or photodiode. In such cases, it is desired to be configured such that only a device whose communication unit has a prescribed relative position can communicate with a printer via optical patterns and the physical proximity between the communication unit of the printer **110** and the communication unit of the mobile information terminal **150** is maintained. Such a configuration is achieved, for example, by increasing the directivity of the emitted or received light. Alternatively, a method may be adopted that performs communication via sound-wave patterns using a sound wave generator such as loudspeaker and a sound wave receiver such as microphone. In a similar manner to the cases of optical patterns described above, it is desired to be configured such that only a device whose communication unit has a prescribed relative position can communicate with a printer via optical patterns. Such a configuration is achieved, for example, by increasing the directivity of the generated or received sound waves.

A mobile information terminal such as a known smartphone includes an LED, an illuminance sensor, a loudspeaker, and a microphone. By making use of such existing hardware, cost may be reduced. Alternatively, different direct communication methods may be used between the communication channel from the printer **110** to the mobile information terminal **150** and the communication channel from the mobile information terminal **150** to the printer **110**.

As illustrated in FIG. 2, the hardware configuration of the printer **110** further includes a controller **112**, a memory **120**, a real time clock (RTC) **122**, an operation panel **124**, a communication interface (I/F) **126**, and a printer engine **128**,

and these elements are controlled by a control program stored, for example, in the ROM of the controller **112**.

The RTC **122** outputs the data of date, and normally indicates the same date as that of the RTC **160** of the mobile information terminal **150**. The controller **112** receives the output data of the date at the time when proximity is detected. In the example embodiment described below, the controller **112** receives the date from the RTC **122**. However, no limitation is indicated therein, and the date may be obtained from an external time providing system through the communication I/F in other example embodiments.

The memory **120** stores an authentication database (DB) in which the authentication data of all the users registered in the printer **110** is written. The memory **120** includes a hard disk drive (HDD), a solid state disk (SSD), and a nonvolatile memory. In the example embodiment described below, the memory **120** of the printer **110** stores the authentication DB. However, no limitation is indicated therein, and an external authentication server that is connected to the printer **110** through a communication line may store the authentication DB in other example embodiments. Moreover, such an external authentication server may be connected to a plurality of printers through a communication line, and the authentication DB may be shared or synchronized among the printers in other example embodiments.

The operation panel **124** receives instructions such as printing instructions from a user, and displays the results of processes. The operation panel **124** includes a display device such as a display device and an input device such as buttons. The communication I/F **126** connects the printer **110** to the network such as the local area network (LAN), and is used to receive printing data. The communication I/F **126** may be a network interface card (NIC) or a wireless network adaptor. The printer engine **128** performs image formation based on the received printing data, and forms an image on a transferring member such as paper.

In the example embodiment described below, the operation panel **124** of the printer **110** become available after printing data is received through the communication I/F **126** and then a user is authenticated by using the mobile information terminal **150**. Then, as instructed by the user through the operation panel **124**, the printer engine **128** performs printing operation.

The controller **112** includes hardware such as a central processing unit (CPU), a random access memory (RAM), and a read only memory (ROM). The CPU reads a control program from the ROM or other storage device such as a HDD or an SSD and develops the read control program in the workspace provided by the RAM, to realize several functions as will be described later.

As illustrated in FIG. 2, the hardware configuration of the mobile information terminal **150** further includes a controller **152**, a memory **158**, an RTC **160**, and a touch panel **162**, and these elements are controlled by a control program stored, for example, in the ROM of the controller **152**.

The RTC **160** outputs the data of date, and normally indicates the same date as that of the RTC **122** of the printer **110**. The controller **152** receives the output data of the date on which the authentication process started. In the example embodiment described below, the mobile information terminal **150** includes the RTC **160**. However, no limitation is indicated therein, and the date may be obtained from an external time providing system through the communication I/F or the date may be input by a user through an input device such as the touch panel **162** in other example embodiments.

The memory **158** stores the authentication data of a user who is registered in advance such that the user is authenticated by using the mobile information terminal **150**. The memory **158** may be a removable media such as a nonvolatile memory and an SD card (registered trademark), or an auxiliary storage device such as a HDD and an SSD. The authentication data may be prepared in advance by a user or administrator, or the authentication data may be input by a user each time when the user wishes to start authentication processes. The touch panel **162** is composed of, for example, a display and buttons, and is used to input the authentication data of a user.

The controller **152** includes hardware such as a CPU, a RAM, and a ROM. The CPU reads a control program from the ROM or other storage device such as an external nonvolatile memory, an HDD, an SSD, and a removable media and develops the read control program in the workspace provided by the RAM, to realize several functions as will be described later.

FIG. 3 is a functional block diagram of the authentication print system **100** according to the first example embodiment of the present invention. The functional blocks of the printer **110** are firstly described below with reference to FIG. 3. As illustrated in FIG. 3, the functional blocks **210** of the printer **110** include an authentication starter **212**, a generation-code generator **214**, an encoder **216**, a direct output unit **218**, an authenticator table preparation unit **220**, an authentication DB **222**, a date storage unit **224**, and a hash function **226**.

The authentication starter **212** serves as a trigger detection unit for detecting an event that triggers authentication processes and starting the authentication processes. In the example embodiment described below, the authentication starter **212** includes the proximity sensor **118** illustrated in FIG. 2 and a program for processing the output of the proximity sensor **118**.

The generation-code generator **214** serves as a generator that generates an authenticator generation code used as source code for generating a temporary authenticator, as will be described later. No limitation is indicated, but the generation-code generator **214** is configured in the controller **112** by a pseudorandom number generation program such as the Mersenne Twister, the multiply-with-carry, and the Lagged Fibonacci generator. Alternatively, the generation-code generator **214** may be configured by hardware random number generator.

The encoder **216** performs encoding by adding redundancy for error correction to the authenticator generation code generated by the generation-code generator **214**, and by embedding clock signals on the authenticator generation code. No limitation is indicated, but the encoder **216** is configured in the controller **112** by a transmittal code generation program in which an error correction code algorithm such as the Reed-Solomon code and the Bose-Chaudhuri-Hocquenghem (BCH) code and a conversion algorithm such as the 8b/10b code conversion are combined. Alternatively, the encoder **216** may be configured by hardware such as a circuit. In the Reed-Solomon code, for example, a codeword of 24 bits including four 4-bit symbols and two 4-bit redundant symbols may be used.

The direct transmitter **218** converts the authenticator generation code that is generated by the generation-code generator **214** and then is encoded by the encoder **216** into an electrical signal, and drives the vibrator **114** to transmit vibration patterns to the mobile information terminal **150** that requests authentication. No limitation is indicated, but

the direct output unit **218** includes the vibrator **114** illustrated in FIG. **2** and a driver or program that drives the vibrator **114**.

After transmitting the authenticator generation code to the mobile information terminal **150** as vibration patterns, the printer **110** receives a response from the mobile information terminal **150**. The authenticator table preparation unit **220** serves as an authenticator generation unit that generates data for determining whether or not the response from the mobile information terminal **150** is to be accepted or rejected. More specifically, the authenticator table preparation unit **220** prepares temporary authenticators for all the users of the printer **110** based on the authenticator generation codes generated by the generation-code generator **214**.

The authentication DB **222** is a database in which authentic users of the printer **110** are registered, and stores the authentication data of all the users of the printer **110**. The authentication data is uniquely assigned to each of the users, and is used to generate a temporary authenticator for each of the users together with the authenticator generation code.

The date storage unit **224** serves as an authenticating-side synchronous numbering unit that obtains the date on which the authentication process started (at the time when proximity is detected) from the RTC **122** and obtains synchronization information. Here, the date is synchronization information used for synchronization with the mobile information terminal **150**, and is used to generate a temporary authenticator for each of the users together with the authenticator generation code and the authentication data of the users. If such date data is used, synchronization can be performed by using an existing RTC available at a known information processing device or mobile information terminal. Accordingly, the cost may be reduced.

The hash function **226** is a function of difficulty in inverse operation from output to input. The hash function **226** receives the authenticator generation code, the date data, and the authentication data of a user, and outputs a temporary authenticator of fixed length. The hash function **226** is shared with the mobile information terminal **150**, and is configured to output the same data for the same input. No limitation is indicated, but the hash function **226** is configured in the controller **112** by a hash function program such as the Secure Hash Algorithm-1 (SHA-1), the SHA-3, the SHA-256, and the message digest algorithm-5 (MD-5).

The date storage unit **224** outputs the same value as that of the to-be-authenticated-side synchronous numbering unit during a prescribed period, and maintains difficulty in performing inverse operation from the temporary authenticator to the authentication data during the period as the value changes after the period. In the example embodiment described herein, the synchronization information is obtained on a daily basis, and the same value is output as the synchronization information until the day changes. However, no limitation is indicated herein, and the period may be extended or divided into shorter periods by hour or minute according to the length of the temporary authenticator or the desired level of security.

The authenticator table preparation unit **220** according to the present example embodiment inputs the authenticator generation codes generated by the generation-code generator **214**, the date data stored in the date storage unit **224**, and authentication data registered in authentication DB **222** to the hash function **226**, and prepares temporary authenticators for the authentication data of all the users. The prepared temporary authenticators are stored, for example, in data base such as the authentication DB **222**, as a table of the authentication data. The authenticator table preparation unit

220 is configured in the controller **112** by a program that obtains authentication data from the authentication DB **222** and activates the hash function **226** to obtain calculation results.

After the vibration patterns are transmitted from the printer **110** to the mobile information terminal **150**, the mobile information terminal **150** sends back a response to the printer **110** in parallel with the preparation of the table of the temporary authenticators. In order to deal with such a response, the functional block **210** further includes a direct input unit **228**, a decoder **230**, and an authentication processing unit **232**.

The direct input unit **228** drives the vibration sensor **116** to detect the vibration patterns of the mobile information terminal **150**, and converts the detected vibration patterns into an electrical signal. In the example embodiment described below, the direct input unit **228** includes the vibration sensor **116** illustrated in FIG. **2** and a circuit or program for converting the output of the vibration sensor **116** into a digital signal.

The decoder **230** reproduces the embedded clock from the received signal of the vibration patterns to decode the code, and performs error detection and error correction based on the added redundancy. No limitation is indicated, but the decoder **230** is configured in the controller **112** by a transmittal code decoding program in which an error correction code algorithm such as the Reed-Solomon code and a conversion algorithm such as the 8b/10b encoding are combined to be adapted to the algorithm on the mobile information terminal **150** side. Alternatively, the decoder **230** may be configured by hardware such as a circuit.

The authentication processing unit **232** matches at least some of the code for authentication that is received by the direct input unit **228** as vibration patterns and then is decoded by the decoder **230** with the table of the temporary authenticator that is prepared by the authenticator table preparation unit **220** and then is stored in the authentication DB **222**, to determine whether or not the authentication is successful. In the example embodiment described herein, whether or not the authentication is successful is determined based on the degree of match between some of the code for authentication and the temporary authenticators in the table.

More specifically, the authentication processing unit **232** determines whether any of the temporary authenticators in the table matches some of the code for authentication to a prescribed degree or greater before the entirety of the code for authentication is received from the mobile information terminal **150**. When there is a temporary authenticator that matches some of the code for authentication to a prescribed degree or greater, the authentication processing unit **232** determines that the authentication is successful. Accordingly, whether or not an additional code is necessary with reference to the degree of match is determined, and the length of time required for the authentication can be adjusted according to the error rate in communication. When the error rate in communication is small, the length of time required for the authentication is shortened. The authentication processing unit **232** is configured in the controller **112** by a table searching program such as of a management system of related database.

In the present example embodiment, as illustrated in FIG. **3**, the functional blocks **210** of the printer **110** further include an availability controller **234**, and the availability controller **234** controls the functions of the printer **110** based on a result of the authentication processes performed by the authentication processing unit **232**. The availability controller **234** controls the user interface provided on the operation panel

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124 of the printer 110 according to the result of the authentication processes performed by the authentication processing unit 232, and provides an authenticated user with access to the functions.

To an operator who has failed in the authentication process, a message indicating the failure in authentication is presented on the display of the operation panel 124, and no further operation related to function such as printing and scanning is accepted. To an user who has been successfully authenticated, a window for accessing function is presented on the display of the operation panel 124, and operation related to function such as printing, scanning, photocopying, and facsimile is accepted as authorized.

Next, the functional blocks of the mobile information terminal 150 are described below with reference to FIG. 3. As illustrated in FIG. 3, the functional blocks 250 of the mobile information terminal 150 include a direct input unit 252, a decoder 254, a code-for-authentication generator 256, an authentication data storage unit 258, a date storage unit 260, a hash function 262, an encoder 264, and a direct output unit 266.

The direct input unit 252 drives the vibration sensor 154 to detect the vibration patterns that carry the authenticator generation code from the printer 110, and converts the detected vibration patterns into an electrical signal. No limitation is indicated, but the direct input unit 252 includes the vibration sensor 154 illustrated in FIG. 2 and a circuit or program for converting the output of the vibration sensor 154 into a digital signal.

The decoder 254 reproduces the embeded clock from the electrical signal of the vibration patterns received by the direct input unit 252 to decode the code, and performs error detection and error correction based on the redundancy added on the transmission side. No limitation is indicated, but the decoder 254 is configured in the controller 152 by a transmittal code decoding program that is adapted to the printer 110. Alternatively, the decoder 254 may be configured by hardware such as a circuit.

The code-for-authentication generator 256 generates a code for authentication based on the authenticator generation code that is decoded by the decoder 254 upon being received as vibration patterns by the direct input unit 252 from the printer 110. The authentication data storage unit 258 stores the authentication data assigned to a user who carries the mobile information terminal 150. Note that the authentication data is input to the mobile information terminal 150 in advance by a user who has received the authentication data from the system administrator or other administrators. Here, the authentication data that is stored in the authentication data storage unit 258 is used to generate a code for authentication for each of the users together with the authenticator generation code.

The date storage unit 260 serves as a to-be-authenticated-side synchronous numbering unit that obtains the date on which the authentication process started (at the time when vibrations of the printer are detected) from the RTC 160 and obtains synchronization information. Here, the date is used to generate a code for authentication for each of the users together with the authenticator generation code and the authentication data of the users.

The hash function 262 is a function of difficulty in inverse operation from output to input. The hash function 262 receives the authenticator generation code, the date data, and the authentication data of a user, and outputs a code for authentication of fixed length. The hash function 262 is shared with the printer 110, and is configured to output the same data for the same input.

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The code-for-authentication generator 256 according to the present example embodiment inputs the authenticator generation code received from the printer 110, the date data stored in the date storage unit 260, and the authentication data stored in the authentication data storage unit 258 into the hash function 262, to generate a code for authentication. Because the hash function 262 is shared with the printer 110, as long as appropriate authentication data is stored, the same code for authentication as the temporary authenticator prepared on the authenticating side can be obtained. No limitation is indicated, but the code for authentication generator 256 is configured in the controller 152 by a program.

The encoder 264 performs encoding by adding redundancy for error correction to the code for authentication generated by the code-for-authentication generator 256, and by embedding clock signals on the code for authentication. No limitation is indicated, but the encoder 264 is configured in the controller 152 by a transmittal code generation program whose format is adapted to the printer 110. Alternatively, the encoder 264 may be configured by hardware such as a circuit.

The direct output unit 266 converts the code for authentication that is generated by the code-for-authentication generator 256 and then is encoded by the encoder 264 into an electrical signal, and drives the vibrator 156 to transmit vibration patterns to the printer 110. No limitation is indicated, but the direct output unit 266 includes the vibrator 156 illustrated in FIG. 2 and a driver or program that drives the vibrator 156.

In the above, the hardware configuration and functional configuration of the authentication print system 100 according to the first example embodiment of the present invention have been described. Next, the user authentication processes that are performed by the authentication print system 100 according to the first example embodiment of the present invention are described in detail with reference to the flowchart illustrated in FIGS. 4A and 4B, the data structure illustrated in FIGS. 5A to 5F, and the data structure illustrated in FIGS. 6A to 6C.

FIGS. 4A and 4B are a flowchart of the user authentication processes performed between the printer 110 and the mobile information terminal 150 of the authentication print system 100 according to the first example embodiment of the present invention. Note that the processes that are performed on the mobile information terminal 150 side (S100 to S108) are illustrated in combination with the processes that are performed on the printer 110 side (S200 to S215) in FIGS. 4A and 4B.

As illustrated in FIGS. 4A and 4B, the processes performed on the mobile information terminal 150 side start from step S100 in response to, for example, the turning-on of the power to the mobile information terminal 150. In step S101, the mobile information terminal 150 starts the system. In a similar manner, the processes performed on the printer 110 side start from step S200 in response to, for example, the turning-on of the power to the printer 110. In step S201, the printer 110 starts the system.

After the printer 110 is started, the printer 110 uses the authentication starter 212 to start detecting a proximate object in step S202. The detection of such a proximate object triggers authentication processes. The printer 110 determines whether a proximate object is present in step S203. When no proximate object is detected ("NO" in S203), the process returns to step S202 to wait for a proximate object. On the other hand, when a proximate object is detected ("YES" in S203), the process proceeds to step S204. In particular, when the mobile information terminal 150

touches the proximity sensor **118** of the printer **110**, it is determined that a proximate object is present.

In step **S204**, the printer **110** uses the generation-code generator **214** to generate authenticator generation codes. FIG. **5A** illustrates the data structure of an authenticator generation code used by the authentication print system **100** according to the first example embodiment of the present invention. The authenticator generation code illustrated in FIG. **5A** is configured as a byte string of 4-byte random number.

In step **S205**, the printer **110** uses the encoder **216** to encode an authenticator generation code by giving an error correction code thereto and embedding a clock signal thereon, and generates a transmittal code that can stably be transmitted as vibration patterns. FIG. **6A** illustrates an example of the data structure of transmittal code generated by the printer **110** in the authentication print system **100** according to the first example embodiment of the present invention. The transmittal code illustrated in FIG. **6A** may be configured as a 60-bit (2-word) bit patterns obtained by adding a 16-bit error correction code to a 4-byte authenticator generation code as illustrated in FIG. **5A** and performing 8b/10b code conversion thereon.

In step **S206**, the vibrator **114** of the printer **110** uses the direct output unit **218** to generate vibration patterns indicated by the transmittal code.

Moreover, in concurrently to step **S205** and step **S206**, the printer **110** inputs the authenticator generation codes, the date data, and the authentication data to the hash function **226**, to generate temporary authenticators. Accordingly, a temporary authenticator table of the temporary authenticators and the authentication data of all the users registered in the authentication DB **222** is generated (**S207**).

FIG. **5B** illustrates an example of the data structure of date data used by the authentication print system **100** according to the first example embodiment of the present invention. The date data of FIG. **5B** is composed of 8-byte character strings (byte strings) of date described by the American Standard Code for Information Interchange (ASCII) codes.

FIG. **5C** illustrates an example of the data structure of authentication data used by the authentication print system **100** according to the first example embodiment of the present invention. FIG. **5D** illustrates an example of the data structure of authentication DB used by the authentication print system **100** according to the first example embodiment of the present invention. The authentication data depicted in FIG. **5C** and the authentication data of each user listed in the authentication DB as depicted in FIG. **5D** are composed of variable-length strings (byte strings) in which the authentication data is held. The authentication DB may be arranged as the matrix of the authentication data of all the users, but the authentication DB according to the present example embodiment is listed by user identification data.

FIG. **5E** illustrates an example of the data structure of temporary authenticator used by the authentication print system **100** according to the first example embodiment of the present invention. The temporary authenticator illustrated in FIG. **5E** is configured as the bit pattern of the bit of fixed length that is output from the hash function of the first example embodiment described above. The hash function according to the present example embodiment receives an authenticator generation code of fixed length, date data of fixed length, and a variable-length byte string obtained by combining variable-length authentication data, and outputs a temporary authenticator of fixed-length.

FIG. **5F** illustrates an example of the data structure of a table of temporary authenticators and the corresponding data

used by the authentication print system **100** according to the first example embodiment of the present invention. The table of FIG. **5F** includes all the authentication data registered in the authentication DB **222** and the temporary authenticators generated from the registered authentication data. the example embodiment described herein, the table further includes the corresponding user identification data.

After the vibration patterns are generated in step **S206** of FIGS. **4A** and **4B**, the printer **110** waits for response vibration in steps **S208** and **S209**.

On the other hand, after the mobile information terminal **150** starts operating, the mobile information terminal **150** attempts to detect vibration by using the direct input unit **252** in step **S102**. In step **S103**, the mobile information terminal **150** detects vibration and determines whether the detected vibration can be decoded. When no vibration is detected or when it is determined that the detected vibration cannot be decoded (“NO” in **S103**), the process returns to the step **S102** and the mobile information terminal **150** waits for vibration that can be decoded. Note that vibration other than vibration patterns, such as vibration as environmental noise, is excluded in the present example embodiment described herein.

On the other hand, when it is determined that the detected vibration can be decoded (“YES” in **S103**), the process proceeds to step **S104**. In step **S104**, the mobile information terminal **150** uses the decoder **254** to decode the authenticator generation code transmitted from the printer **110**.

In step **S105**, the mobile information terminal **150** inputs the variable-length byte strings obtained by combining the authenticator generation code received from the printer **110**, the date data of when the vibration was detected, and the authentication data of the user stored in the authentication data storage unit **258** to the hash function, and generates a code for authentication. In a similar manner to the temporary authenticator illustrated in FIG. **5E**, the code for authentication is configured as the bit pattern of the bit of fixed length that is output from the hash function according to the present example embodiment.

In step **S106**, the mobile information terminal **150** uses the encoder **264** to encode a code for authentication by giving an error correction code thereto and embedding a clock signal thereon, and generates a transmittal code that can stably be transmitted as vibration patterns. FIG. **6B** illustrates an example of the data structure of transmittal code generated by the mobile information terminal **150** in the authentication print system **100** according to the first example embodiment of the present invention. The transmittal code depicted in FIG. **6B** is a bit pattern of fixed bit length obtained by adding an error correction code to the bit pattern of fixed length as depicted in FIG. **5E** and by performing 8b/10b code conversion thereon.

For example, when the temporary authenticator has the bit length of 160 and the Reed-Solomon code as a codeword of 24 bits including four 4-bit symbols and two 4-bit redundant symbols is used, a 80-bit error correction code is added to a temporary authenticator of bit length of 160 and 8b/10b code conversion is performed thereon. Accordingly, bit patterns of bit length of 300 are obtained.

In step **S107**, the mobile information terminal **150** uses the direct output unit **266** to generate vibration patterns indicated by the transmittal code, which are to be transmitted from the vibrator **156**. Then, the process shifts to a standby mode in step **S108**.

On the printer **110** side, as described above, after the vibration patterns are generated in step **S206** of FIGS. **4A** and **4B**, the printer **110** waits for response vibration in steps

S208 and S209. In the step S208, the printer 110 attempts to detect vibration by using the direct input unit 228. In step S209, the printer 110 detects vibration and determines whether the detected vibration can be decoded. When no vibration is detected for a prescribed length of time or longer or when it is determined that the detected vibration cannot be decoded (“NO” in S209), the process returns to the step S202. When an object other than the mobile information terminal 150 is detected, the authentication starter 212 starts detecting a proximate object again.

On the other hand, when a part of the vibration patterns is detected and it is determined that the detected vibration can be decoded (“YES” in S209), the process proceeds to step S210. In step S210, the printer 110 uses the decoder 230 to decode the part of the authenticator that has already been received, and prepares a partial code for authentication.

FIG. 6C illustrates an example of the data structure of partial code for authentication generated by the printer 110 in the authentication print system 100 according to the first example embodiment of the present invention. The partial code for authentication depicted in FIG. 6C is composed of a pair of the storage bit string in which the part of the code for authentication of fixed bit length that has already been received is stored and the reception-status bit string indicating the reception status of the code for authentication for each bit.

The reception-status bit string indicates the reception status of the bit patterns of the code for authentication of fixed bit length as described above. In the example embodiment described herein, 2-bit representation is adopted. “00” indicates that the bit patterns are not yet received, and “01” indicates that the reception is complete. “10” indicates that the reception is complete but an error is detected, and “11” indicates that an error is detected in the received code but the code has been corrected by an error correction code. Accordingly, when the authenticator of bit length of 160 as described above is used, the partial code for authentication depicted in FIG. 6C is composed of a pair of the storage bit string of 160 bits and the reception-status bit string of 320 bits

When the decoding is to be started, all the 2 bits of the bit strings that indicates the reception status are initialized to be “00”. When the transmittal code is decoded by the printer 110, the normally-received bits are written into the storage bit string, and the value of the corresponding bit in the reception-status bit string is changed accordingly. By so doing, how far the reception is complete, from which of the received bits an error is detected, and the error of which of the bits has been corrected are managed.

In step S211, the printer 110 searches the table for an authenticator that matches the partial code for authentication to the highest degree. In this search, the partial code for authentication where an error has been corrected by an error correction code may be used. The bit patterns of “01” (reception is complete) and “11” (reception is complete upon correcting the code) are used to perform a partial search on the table. Accordingly, matching authentication data is searched for, and the degree of match is also calculated.

In step S212, the printer 110 determines whether or not any of the matched authenticators in the table has a degree of match equal to or greater than a reference value with the partial code for authentication. The temporary authenticator that is the source of a partial code for authentication is generated by a hash function, and has almost random bit patterns. For this reason, in order to avoid erroneous authentication in which a user is mistaken for a different user, it can be assumed that the authentication was successful when

patterns of sufficient length match in comparison to the square of the number of the users. Assuming that a system includes hundred-thousand users and a temporary authenticator has 160 bits, the probability of matching by chance when 48 bits or more are matched is as low as one in twenty-eight thousands (i.e., about $100,000 \times 100,000 / 281,000,000,000,000$) when each of the all users uses the printer 110 one time. Accordingly, the reference may be set to 48 bits or more. Note that the reference may be determined depending on the level of security required in a specific application.

When it is determined that the matched length is not sufficient for authentication and none of the matched authenticators has a degree of match equal to or greater than a reference value (“NO” in step S212), the process shifts to step S213. In step S213, the printer 110 determines whether or not the entirety of the code for authentication has been received. When the printer 110 determines that the entirety of the code for authentication has not been received (“NO” in step S213), the process returns to the step S209, and the printer 110 waits for additional vibration patterns. On the other hand, when the printer 110 determines that the entirety of the code for authentication has been received (“YES” in step S213), it is determined that the authentication is a failure in step S215 because there is no further possibility for successful authentication. When the printer 110 determines that the matched authenticators in the table has a degree of match equal to or greater than a reference value with the partial code for authentication before the entirety of the code for authentication is received (“YES” in step S212), the printer 110 determines that the authentication is successful in a step S214. By so doing, it becomes possible to complete the authentication processes before the entirety of the transmittal code is received.

In the user authentication processes according to the first example embodiment described above, the printer 110 uses proximity sensor 118 to sense that the mobile information terminal 150 is approaching the printer 110, and generates a source code for user authentication processes. Then, the printer 110 uses the vibrator 114 to generate vibration patterns based on the generated codes. The vibration patterns generated by the vibrator 114 as above are detected by the vibration sensor 154 of the mobile information terminal 150.

The mobile information terminal 150 generates a code for authentication based on the detected source code, the uses the vibrator 156 to generate vibration patterns based on the generated code for authentication. The vibration patterns generated by the vibrator 156 as above are detected by the vibration sensor 116 of the printer 110. The printer 110 performs user authentication by specifying the user indicated by at least some code of the detected authenticator and verifying the authenticator.

[Modification of First Example Embodiment]

In the user authentication as described above, it is undesired, for example, that a user is authenticated by a device other than the target information appliance and a third party uses the device with the authority of the user. Moreover, it is undesired that an unauthorized third party is authenticated by the printer 110 as a particular existing user. When vibration patterns are used for authentication, a known device that is provided for the mobile information terminal 150 cannot shorten the control intervals or detection intervals of the generation and detection of the vibration patterns. For this reason, the communication speed of such a known device may be slowed down, and it may take a long time for authentication.

According to the first example embodiment described above, communication is performed between the printer **110** and the mobile information terminal **150** by using vibration patterns where the range that a signal can reach is limited and a signal can be transmitted only to a contacted communication unit or a signal can be received only from a contacted communication unit. Accordingly, false authentication on the device side and the terminal side, for example, cases in which a user trying to be authenticated by the printer **110** with the mobile information terminal **150** is authenticated by a different device by error, can be prevented, and the tampering of the communication as desired by an external attacker can also be prevented.

Even if the communication is intercepted by a third party, it is difficult to decode the authentication data because a temporary authenticator is valid only temporarily and a hash function has difficulty in inverse operation. Moreover, when date data is used as an input for a hash function as in a particular embodiment of the present invention, it is even more difficult to decode the authentication data. This is because when a temporary authenticator of appropriate fixed bit length is used, it is impossible to decode the authenticator with realistic computational resource within the effective period of the date data.

As described above, with the authentication system according to the first example embodiment, the security of the communication channel between the mobile information terminal **150** carried by a user and the printer **110** is improved, and the length of time required for the successful completion of authentication processes through the communication channel can be shortened.

[Modification of First Example Embodiment]

In the first example embodiment described above, every time authentication procedure is to be started, the authenticators of all the user are prepared based on the authenticator generation code generated on the printer **110** side. Such a configuration is effective, in particular, for a small-scale or medium-scale organization. However, for a large-scale organization or public use, for example, in convenience stores, the load of generating a table as described above may become too large as such load increases by the square of the number of users. An example modification in which the range of a table to be generated is limited and the load of generating the table is reduced is described below.

FIG. 7A illustrates an example of the data structure of authentication DB used by the authentication print system **100** according to the modification of the first example embodiment of the present invention. FIG. 7B illustrates an example of the data structure of a table of temporary authenticators and the corresponding data used by the authentication print system **100** according to the modification of the first example embodiment of the present invention. In a similar manner to the first example embodiment described above, the authentication DB depicted in FIG. 7A includes all the authentication data registered in the authentication DB **222**. In the present example modification, a password is added to the tail end of each of the user IDs in the authentication data.

In the present example modification, the mobile information terminal **150** firstly generates a search reference value based on the authenticator generation code received from the printer **110**. Secondly, the mobile information terminal **150** compares the generated search reference value with the user ID included in the authentication data stored in the authentication data storage unit **258**, and adds the result of the comparison to the head of the generated code for authentication. Then, the mobile information terminal **150** transmits

the code for authentication to the printer **110** as vibration patterns. Here, the result of the comparison indicates whether each of the user IDs included in the authentication data is greater or smaller than the search reference value.

On the other hand, the printer **110** also generates a search reference value based on the authenticator generation codes generated by the generation-code generator **214**, in a similar manner to the mobile information terminal **150** as described above. In the present example modification, the generation of a table in the step **S207** as illustrated in FIGS. 4A and 4B does not start immediately after the generation of the authenticator generation code. Instead, the printer **110** extracts the result of the comparison when the reception of a code corresponding to the result of the comparison is complete while receiving a code for authentication, and generates a table of the temporary authenticators for only the authentication data of the user IDs specified by the result of the comparison. In the example depicted in FIG. 7B, the table is generated only for the authentication data where the head of the user ID is less than seven.

As the search reference value is generated in the same way as mobile information terminal **150**, the same value is output for the generated authenticator generation code by the mobile information terminal **150** and the printer **110**. For this reason, it becomes possible for the printer **110** to specify group of authentication data that includes the authentication data of the user of the mobile information terminal **150**, based on the result of the comparison. The steps after the table is generated are equivalent to those of the first example embodiment described above.

According to the present example modification described above, the load of generating the table is reduced as the table of temporary authenticators is generated only for the specified authentication data, and the length of time required for the authentication can also be reduced. In particular, the example modification is effectively applied when the number of users is enormously large. Moreover, as a search reference value is generated based on the authenticator generation code, the range of the table of temporary authenticators can efficiently be limited even if the user IDs are biased compared with cases in which the search reference value is fixed. In the example embodiment described above, a single search reference value is used. However, a plurality of search reference values and a plurality of results of comparison may be used, for example, for the first two digits of each of the user IDs, to further limit the range in which the table is to be generated.

[Second Example Embodiment]

The first example embodiment has been described as above with reference to the authentication print system **100** that includes the mobile information terminal **150** carried by a system user and the printer **110** that performs authentication processes, where the operation of the printer **110** is controlled according to a result of the authentication processes. The second example embodiment is described below with reference to the authentication print system **100** that includes the mobile information terminal **150**, a plurality of readers **140** and printers **110**, and an authentication server **170**. The mobile information terminal **150** is carried by a system user, and the readers **140** receive authentication requests. The operation of the printers **110** is controlled according to results of the authentication processes.

FIG. 8 is a diagram illustrating an outline of the configuration of a authentication print system **100** according to the second example embodiment of the present invention. As illustrated in FIG. 8, the authentication print system **100** according to the second example embodiment of the present

invention includes a plurality of printers **110a** to **110z** that cannot be used unless authenticated, readers **140a** to **140z** provided for the respective printers **110a** to **110z**, an authentication server **170** connected to the printers **110a** to **110z** through a network **102**, and the mobile information terminal **150** carried by a user.

In the authentication print system **100** according to the second example embodiment of the present invention, the interfaces with the mobile information terminal **150** are the readers **140** that are provided for the respective printers **110** to communicate with the associated printers **110**, and each of the readers **140** is an authentication device that receives an authentication request. When the mobile information terminal **150** is placed on the reader **140** provided for the printer **110**, the reader **140** and the mobile information terminal **150** can communicate with each other as the communication units of the printer **110** and the mobile information terminal **150** contact. Data for authentication is exchanged between the reader **140** and the mobile information terminal **150** through mechanical vibration patterns. The readers **140** are connected with the printers **110**, for example, through universal serial buses (USBs), and the printers **110** communicate with the authentication server **170** through the network **102** to perform user authentication.

FIG. **9** is a functional block diagram of the authentication print system **100** according to the second example embodiment of the present invention. The functional blocks **210**, **240**, **250**, and **270** of the printer **110**, the reader **140**, the mobile information terminal **150**, and the authentication server **170**, respectively, are described below with reference to FIG. **9**.

As illustrated in FIG. **9**, the functional blocks **210** of the printer **110** according to the second example embodiment of the present invention includes an availability controller **234**. The functional blocks **240** of the reader **140** according to the second example embodiment of the present invention includes an authentication starter **241**, an encoder **242**, a direct output unit **243**, a direct input unit **244**, and a decoder **245**. The functional blocks **270** of the authentication server **170** according to the second example embodiment of the present invention includes a generation-code generator **272**, an authenticator table preparation unit **274**, an authentication DB **276**, a date storage unit **278**, a hash function **280**, and an authentication processing unit **282**. The functional blocks **250** of the mobile information terminal **150** according to the second example embodiment of the present invention are equivalent to those of the first example embodiment.

The generation-code generator **272** of the authentication server **170** according to the second example embodiment generates a at least one authenticator generation code in advance. The authenticator table preparation unit **274** prepares the table of temporary authenticators for all the users of the printer **110** based on the at least one of authenticator generation codes that are generated in advance by the generation-code generator **272**.

The generation-code generator **272** of the authentication server **170** transmits an authenticator generation code to be used for the ongoing authentication to the encoder **242** of the reader **140**, in response to the instructions for starting authentication sent from the authentication starter **241** of the reader **140**. The communication between the reader **140** and the authentication server **170** is performed by the communication I/F through the printer **110**.

The encoder **242** of the reader **140** encodes the authenticator generation code received from the generation-code generator **272** of the authentication server **170**. The direct output unit **243** converts the authenticator generation code

encoded by the encoder **242** into an electrical signal, and drives the vibrator to transmit vibration patterns to the mobile information terminal **150**.

The direct input unit **244** of the reader **140** drives the vibration sensor to sense the vibration patterns of the mobile information terminal **150**, and converts the detected vibration patterns into an electrical signal. The decoder **245** reproduces the embedded clock from the received signal of the vibration patterns to decode the code, and performs error detection and error correction based on the added redundancy. Then, the decoder **245** transmits the obtained code to the authentication processing unit **282** of the authentication server **170** as necessary.

FIG. **10** illustrates an example of the data structure of a table of temporary authenticators and the corresponding data used by the authentication print system **100** according to the second example embodiment of the present invention. As depicted in FIG. **10**, the table that is prepared by the authenticator table preparation unit **274** according to the second example embodiment includes all the authentication data registered in the authentication DB **222**, the temporary authenticators generated from the registered authentication data, and flags that indicate whether the temporary authenticators are valid or invalid. Note that the table is paired with at least one generated authenticator generation code.

The authentication processing unit **282** matches at least some of the code for authentication, which is received by the direct input unit **244** of the reader **140** as vibration patterns and then is decoded by the decoder **245**, and is transmitted to the authentication processing unit **282** through a communication I/F as necessary, with the table of the temporary authenticator that is prepared by the authenticator table preparation unit **274** and then is stored in the authentication DB **276**, to determine whether or not the authentication is successful. In a similar manner to the example embodiment described above, whether or not the authentication is successful is determined based on the degree of match between some of the code for authentication that is received as necessary and the temporary authenticators in the table, in the second example embodiment described herein.

When determined that the authentication was successful, the authentication processing unit **282** according to the second example embodiment sets the flag that corresponds to the matched authenticator to "true" in the table of the transmitted authenticator generation code. Accordingly, the authenticator is invalidated. Such an invalidated authenticator cannot be used any longer. For example, even if an attacker that has intercepted the temporary authenticator transmitted from the mobile information terminal **150** transmits the same temporary authenticator, or even if the same authenticator generation code is transmitted to, the authentication ends in failure. When an authentication request is sent from a different mobile information terminal to another printer (e.g., a printer separate from the printer to which an authentication request was sent from the first user), the generation-code generator **272** may transmit the same authenticator generation code. When the same authenticator generation code is used, the table can be reused.

The availability controller **234** according to the second example embodiment of the present invention controls the user interface provided on the operation panel **124** of the printer **110** according to the result of the authentication processes performed by the authentication processing unit **282** of the authentication server **170**, and provides an authenticated user with access to the functions.

If the same authenticator generation code is successively transmitted from the same printer **110**, the temporary

authenticator is already invalidated for the same user. Accordingly, the authentication requested by the user ends in failure even if the authentication data is authentic, and the user is required to repeat the procedure. This may lower the customer convenience. In view of the above circumstances, it may be configured such that the same printer according to the present example embodiment basically does not successively transmit the same authenticator generation code. On the other hand, a printer that is sufficiently distant and is not likely to be used by the same user according to the position information of the printers may be configured to reuse the table and transmit the same authenticator generation code that has already been transmitted to the user. Due to such a configuration, the table may be reused, and the customer convenience does not suffer even when the same user is up to the authentication for the second time.

According to the second example embodiment described above, the authentication server **170** is shared among the multiple printers **110** and the table is reused. Thus, the load of generating a table can be reduced as a whole. According to the second example embodiment described above, the authentication processes of the multiple printers **110** are performed by a single authentication server in an integrated manner. Accordingly, an increase in the load of generating a table and the length of time required to perform authentication processes due to the increased scale can be attenuated by reusing the table among the multiple printers **110**. Moreover, the controllability or convenience improves as the user data of a plurality of printers is shared.

According to the example embodiments described above, an authentication system and authentication method can be provided in which the security of the communication channel between a mobile device carried by a user and an authentication device that authenticate the mobile device is improved.

In the example embodiments described above, temporal patterns in mechanical vibration are used as patterns that are transmitted. However, no limitation is indicated therein, and the transmitted patterns may include spatial components generated by a plurality of channels.

The functional part as described above is realized by a computer-readable program written by legacy programming language or object-oriented programming language such as assembler language, C language, C++ language, C# language, and Java (registered trademark), and the program can be distributed via telecommunication line or upon being written on a computer-computer-readable recording medium such as ROM, electrically erasable and programmable read only memory (EEPROM), electrically programmable read only memory (EPROM), flash memory, flexible disk, compact disc read only memory (CD-ROM), compact disc rewritable (CD-RW), digital versatile disk (DVD)-ROM, DVD-RAM, DVD-RW, Blu-ray disc, secure digital (SD) card, and magneto-optical disc (MO).

Embodiments of the present invention has been described above, but the present invention is not limited to those embodiments and various applications and modifications may be made without departing from the scope of the invention.

Numerous additional modifications and variations are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the disclosure of the present invention may be practiced otherwise than as specifically described herein. For example, elements and/or features of different illustrative embodi-

ments may be combined with each other and/or substituted for each other within the scope of this disclosure and appended claims.

Further, as described above, any one of the above-described and other methods of the present invention may be embodied in the form of a computer program stored in any kind of storage medium. Examples of storage mediums include, but are not limited to, flexible disk, hard disk, optical discs, magneto-optical discs, magnetic tapes, non-volatile memory cards, ROM, etc. Alternatively, any one of the above-described and other methods of the present invention may be implemented by ASICs, prepared by interconnecting an appropriate network of conventional component circuits, or by a combination thereof with one or more conventional general-purpose microprocessors and/or signal processors programmed accordingly.

What is claimed is:

1. An authentication system comprising:

a mobile device including mobile device circuitry configured to
 store authentication data of a user,
 generate a code for authentication using a prescribed code and the authentication data,
 control generation of a mechanical vibration pattern based on the code for authentication,
 control sensing of a mechanical vibration pattern to obtain the prescribed code,
 generate a search reference value based on the prescribed code,
 compare the generated search reference value with a user identifier included in the authentication data to output a comparison result, and
 add the comparison result to the code for authentication to be output; and
 an authentication device configured to authenticate the user at the mobile device, the authentication device including
 a proximity sensor configured to detect the mobile device when the mobile device is within a proximate distance of the authentication device, and
 authentication device circuitry configured to
 output the prescribed code to be used for generating the code for authentication in response to detection of the mobile device by the proximity sensor,
 control generation of a mechanical vibration pattern that is transmitted to the mobile device, based on the prescribed code,
 control sensing of a mechanical vibration pattern that is received from the mobile device,
 obtain the code for authentication based on the received mechanical vibration pattern
 obtain authentication data of one or more registered users from a memory, and generate an authenticator for each one of the one or more registered users, by using the prescribed code and authentication data of corresponding one of the one or more registered users, and
 match the code for authentication output from the mobile device with the authenticator that is generated for each one of the one or more registered users to determine whether the user at the mobile device is authenticated.

2. The authentication system according to claim **1**, wherein the authentication device circuitry is further configured to generate an authenticator generation code as the prescribed code.

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3. The authentication system, according to claim 2, wherein

the authentication device circuitry is further configured to obtain synchronization information, the authenticator being generated from the synchronization information, the authenticator generation code, and the authentication data,

the mobile device circuitry is further configured to obtain synchronization information, the code for authentication being generated from the synchronization information, the authenticator generation code received from the authentication device, and the authentication data of the user, and

the authentication device circuitry and the mobile device circuitry output a same value for a prescribed period of time.

4. The authentication system according to claim 3, wherein the authentication device circuitry and the mobile device circuitry output date data of when the authentication started as the synchronization information.

5. The authentication system according to claim 1, wherein the authentication device circuitry is further configured to detect an event that triggers detection of the mobile device.

6. The authentication system according to claim 1, wherein the authentication device circuitry is further configured to determine whether or not the user at the mobile device is authenticated based on a degree of match between at least a portion of the code for authentication and the authenticator of each one of the one or more registered users.

7. The authentication system according to claim 6, wherein the authentication device circuitry is further configured to determine, for at least one of the authenticators of the one or more registered users, whether the authenticator matches the code for authentication to a prescribed degree before an entirety of the code for authentication is obtained from the mobile device, and determines that the user at the mobile device is authenticated when there is at least one authenticator that matches the code for authentication to the prescribed degree.

8. The authentication system according to claim 1, wherein

the authentication device and the mobile device exchange data through a communication channel where a signal is transmitted or received only when the mobile device is made in contact with or near the authentication device.

9. The authentication system according to claim 1, wherein

the authentication device further includes a light emitting element configured to emit an optical pattern based on the prescribed code, and

the mobile device includes a light receiving element configured to receive the optical pattern emitted by the light emitting element to obtain the prescribed code.

10. The authentication system according to claim 1, wherein

the mobile device includes a light emitting element configured to emit an optical pattern based on the code for authentication, and

the authentication device includes a light receiving element configured to receive the optical pattern to obtain the code for authentication.

11. The authentication system according to claim 1, wherein

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the authentication device circuitry is further configured to generate the authenticator for each one of the one or more registered users in advance using the prescribed code, and

when it is determined that the user at the mobile device is authenticated, the the circuitry is configured to invalidate the prescribed code for the authenticator that matches the code for authentication, while keeping a pair of the prescribed code and the authenticator for the one or more registered users other than the authenticated user for later use.

12. The authentication system according to claim 1, wherein

the authentication device circuitry is further configured to generate a search reference value using the prescribed code,

extract the comparison result from the code for authentication, and

determine a range of the authentication data for which the authenticator is to be generated based on the search reference value generated at the authentication device and the comparison result extracted from the code for authentication.

13. The authentication system according to claim 1, wherein the prescribed code is generated using a prescribed function that is a hash function that has at least the prescribed code and the authentication data as an input value and the authenticator or the code for authentication as an output value.

14. The authentication system according to claim wherein the authentication device includes:

a server; and

a device that operates under control of the server based on an authentication result output by the server.

15. An authentication device comprising:

a proximity sensor configured to detect a mobile device when the mobile device is within a proximate distance of the authentication device; and

circuitry configured to

output a prescribed code in response to detection of mobile device by the proximity sensor,

control generation of a mechanical vibration pattern that is transmitted to the mobile device, based on the prescribed code,

control sensing of a mechanical vibration pattern that is received from the mobile device,

obtain a code for authentication based on the received mechanical vibration pattern, using the prescribed code and authentication data of a user stored in the mobile device, the code for authentication including a comparison result between a search reference value and a user identifier included in the authentication data, the search reference being generated by the mobile device based on the prescribed code,

obtain authentication data of one or more registered users from a memory,

generate an authenticator for each one of the one or more registered users, by using the prescribed code and authentication data of corresponding one of the one or more registered users, and

match the code for authentication output from the mobile device with the authenticator that is generated for each one of the one or more registered users to determine whether the user at the mobile device is authenticated.

16. An authentication method performed by an authentication device, the method comprising:

detecting a mobile device when the mobile device is
within a proximate distance of an authentication
device;
generating a mechanical vibration pattern and outputting
a prescribed code in response to detection of mobile 5
device through the generated mechanical vibration pat-
tern;
obtaining a code for authentication output from the
mobile device through a mechanical vibration pattern
that is generated at the mobile device using the pre- 10
scribed code and authentication data of a user stored in
the mobile device, the code for authentication including
a comparison result between a search reference value
and a user identifier included in the authentication data,
the search reference being generated by the mobile 15
device based on the prescribed code;
reading authentication data of one or more registered
users from a memory;
generating an authenticator for each one of the one or
more registered users, by using the prescribed code and 20
authentication data of corresponding one of the one or
more registered users; and
matching the code for authentication output from the
mobile device with the authenticator that is generated
for each one of the one or more registered users to 25
determine whether the user at the mobile device is
authenticated.

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